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ABSTRACT

The interpretation of dental X-rays by novices (students) and experts (dentists practicing more than 3 years) was compared. Eight fifth-year novices and eight experts were presented three types of problem X-ray (easy, difficult, and control). Experts were faster in solving the problems and their diagnoses were more accurate. Analysis of eye movement patterns during the first second indicated differences in problem solving approaches. Students paid more attention to conspicuous areas, while dentists attended more to cognitive conspicuous areas (i.e., areas attracting attention because of possible significance of diagnosis). Students' attention for visually conspicuous areas resulted in a lower information gain during the first second. Processing time also showed an expertise effect, which was most evident in control problems. Dentists first inspected the whole X-ray, and then tried to formulate solutions, whereas the students tried to solve the problem immediately. Differences between students and dentists are discussed in terms of eye movement pattern and pupil size. Ten sample X-rays are included. (SW)

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The effect of different levels of expertise
on interpretation of dental X-rays

Paper presented at the AERA annual meeting 1984

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ABSTRACT

Interpreting dental X-rays (diagnosis) can be looked upon as medical problem solving. Judgements about the nature of a pathology from X-ray photographs by 'novices' (students) and experts (dentists) might, assuming that both groups of subjects are capable of making a diagnosis, be expected to differ. Novices and experts in this research programme were presented with three types of problem (easy, difficult, control). Experts were faster in solving the problems and their diagnoses were more accurate. Analysis of eye movement patterns during the first second indicated differences in problem solving approaches: students paid more attention to visual conspicuous areas, dentists to cognitive conspicuous areas. Such differences between students and dentists are discussed in terms of eye movement pattern and pupil size.

INTRODUCTION

Assuming that both novices and experts are able to solve a presented problem, differences in their knowledge of a given domain affect their problem solving in that domain. Research into differences in approach and method of problem solving between persons with different levels of expertise initially received attention in the game of chess (De Groot, 1965). In more recent research, problems in physics and information science were presented for solution (Simon and Simon, 1978; Larkin, Mc Dermott, Simon and Simon, 1980; Adelson, 1981). Some research on medical diagnosis has also been reported (Elstein, Shulman & Sprafka, 1978; Johnson, Duran, Hassebrock, Moller, Pietula, Feltovich & Swanson, 1982).

Medical diagnosis, whether carried out by a physician, a dentist or a medical specialist can be looked upon as problem solving. Diagnosing consists of generating an hypothesis, testing it and evaluating it. Generating an hypothesis is based on both symptoms (given) and knowledge. Success in diagnosing depends on the ability to recognize a symptom or pattern of symptoms, characteristic for the prototypical syndrome (Johnson, Feltovich, Moller & Swanson, 1979). A prototype is the central tendency of examples (elements) of a category, based on the frequency of occurrence of attributes (values on a dimension) of those examples. The prototype is represented in long term memory. It is assumed to be a point in a fuzzy multi-dimensional set. The position of the prototype is dependent on its values on different dimensions. During diagnosis, knowledge about pathologies (diseases) has to be retrieved from long term memory: symptoms are compared with the prototypical image, which can be considered a part of the declarative body of knowledge (The body of knowledge can be split into declarative and procedural knowledge.

In addition, meta knowledge - knowledge about the accessibility and organisation of one's own knowledge - can be distinguished).

Diagnosing may give rise to errors (Johnson et al., 1982). It is assumed that novices make errors on the dimension of typicality. Either setting the borders of the set too narrow (i.e. not recognizing a feature of disease on set) or too broad. Experts may choose a wrong track based on irrelevant cues which a novice might not even notice. Interpreting dental X-rays demands perceptual skill as well as diagnostic reasoning skills (Kreps, Kraft, Burris, Isch, Olson, Smith & Krabinos, 1979). Two types of perceptual skill are necessary. Firstly, the ability to recognise deviations from the 'normal' image and label it with reference to other pathologies. The course of the inspection process can be studied by recording eye movement patterns. The visual scanning and recognition process may be studied satisfactorily in a quantitative way by recording the eye movements of the observer (Kundel & Nodine, 1978; De Valk, 1983). Differences in eye movement patterns between novices and experts may be found and related to underlying cognitive processes in so far as these can be unravelled. Kundel and Wright (1969) studied the influence of available knowledge on eye movement patterning. Subjects, when they had to look for something specific, showed a common pattern. Kundel and Lafolette (1972) showed differences in eye movement patterning in inspecting thorax X-rays between subjects at different levels of a training course for radiologists. It is concluded that differences in attention are based on knowledge differences.

A dental X-ray contains black-white gradations, some of which are even conspicuous for a layman and comprise a form of elements, figure-ground segregation and restorations. Engel (1976) defines these as visually conspicuous. Cognitive conspicuous areas are those attracting attention because of possible significance of diagnosis.

A pathology is characterized by a deviant blackness. This has to be interpreted in relation to the prototype of the disease. Differences in the course of interpretation are reflected in eye movement patterns. It is predicted that novices will pay more attention to visually conspicuous areas than experts, especially at the start of the inspection process. Experts will pay more attention to cognitive conspicuous areas and will gain more information, because they probably have more knowledge about which areas could contain information about pathologies. In addition, experts will be faster in processing the information and will formulate more accurate diagnoses. Accuracy is defined as certainty related to correctness. There are two extreme values: hypothesis correct and 100% certainty yields an accuracy score of +100, hypothesis incorrect and 100% certainty yields an accuracy score of -100.

If black-white gradations make a dental disease difficult to identify more effort will be necessary in diagnosing. Pupil size will reflect effort differences. Evidence of identifying something deviant on the X-ray is shown if pupil dilation corresponds with the inspection of a cognitive conspicuous area (Kahneman, 1973).

METHOD

Subjects.

Eight 5th year dentistry students and eight experienced dentists participated voluntarily in the experiment. Experienced dentists had practised more than three years.

Materials.

Nine problems (X-rays) were selected. Two X-rays showed a caries problem, two a bone resorption problem and two a periapical lesion.

Each pair contained an easy and a difficult example (typical and atypical) as rated by two radiologists. Three control X-rays showed no dental disease. One radiologist marked areas as visual, cognitive conspicuous or both.

Apparatus.

A Whithaker Eye-View Monitor was used for recording eye movements. Registration of inspection points occurs every 20 msec. Two or more points coincide when their distance is zero. A fixation is a coincidence of inspection points during approximately 200 msec. (It is assumed that verbalising a decision takes approximately 400 msec.) An Apple-II micro processor was used to store these data on floppy-disc. Processing time was registered by a timer. X-rays were projected on to a screen in front of subjects by means of a slide projector.

Procedure.

The problems were randomly presented. Each slide was preceded by a slide with five reference points by which means the apparatus could be adjusted. Subjects controlled presentation by keeping a button pressed. Eye movement pattern and pupil size were recorded. Releasing the button indicated a solution to the problem, after which subjects formulated their solution (verbal report) and indicated their degree of certainty about it (percentage score).

Design.

The dependent variables were processing time and certainty index. Processing time is the total time necessary for gathering information. Analysis of data was carried out using a 2 (levels of expertise) x 3 (problem type: simple (typical), difficult (atypical), control) complete factorial design.

Eye movement patterns were analysed by relating fixations to conspicuous areas. These areas were marked on X-rays by two radiologists who separated them into visual and cognitive conspicuous areas.

RESULTS

Conspicuous areas.

Table 1 shows the distribution of inspection points and their clusters during the first second of observation for the two levels of expertise. Dentists inspected more cognitive conspicuous areas than the novice students. Contingency analysis yielded a significant difference ($X^2 = 5.99$, $p < 0.25$).

Insert Table 1 about here

Information gain.

Information gain is defined as the number of cognitive conspicuous areas observed during the first second, divided by the total sum of cognitive conspicuous areas. Analysis of information gain scores showed a significant difference between students and dentists, $t_{88} = 1.85$, $p < .05$. Analysis of the coinciding points during the first second shows the same trend, $t_{88} = 45.63$, $p < .01$.

Processing time.

Students' mean processing times for easy, difficult and control problems were respectively 46.9 sec., 46.62 sec. and 48.29 sec., those of dentists respectively 42.74 sec., 39.06 sec. and 38.97 sec. (Fig. 1). Analysis of variance of processing time showed a significant expertise effect, $F(1,106) = 2.79$, $p < .10$.

Insert Figure 1 about here

Accuracy.

Students' mean accuracy scores for easy, difficult and control problems were 60.72, 49.29 and -17.78 respectively, those for dentists 64.19, 55.24 and 31.46 respectively (Fig. 2).

Analysis of variance of accuracy scores showed a significant expertise effect, $F(2.138) = 20.30$, $p < .001$.

Insert Figure 2 about here

Eye movement pattern and pupil size.

A typical example of a section of the eye movement pattern of a dentist is shown in Figure 3, that of a student in Figure 4. Figure 5 shows the changes in pupil size during the search processes of the subjects referred to in Figures 3 and 4.

Insert Figures 3, 4 and 5 about here

The mean pupil diameter of the student was 170.08 scanlines and that of the dentist 174.18 scanlines (1 scanline = 0.04 mm).

DISCUSSION

The analysis of attention for conspicuous areas during the first second of observation confirms the original hypothesis. Students pay more attention to visually conspicuous areas, whereas both groups inspect roughly the same

number of areas. The course of this inspection process is related to the difference in information gain between dentists and students. Students' attention for visually conspicuous areas results in a lower information gain during the first second.

Processing time also shows an expertise effect, which is most evident in control problems. Analysis of accuracy scores shows that dentists make qualitatively better diagnoses than students. Also less errors are made.

Subjects from the two groups set the borders of the fuzzy set with varying accuracy. Students may even have negative accuracy scores.

Interpretation of eye movements based on the cases presented in Figures 3, 4 and 5 will be discussed. Eye movement patterning is related to variations in pupil size as an indicator of mental load during problem solving. Pressing a button leads to the presentation of a problem and the registration of eye movement pattern and pupil diameter. The subject is in a dark cabin. At the beginning of the search process the light from the X-ray presented causes constriction of the pupil (Fig. 5). The dentist's inspection of the X-ray during the first 6 seconds requires very little mental load. Thereafter he inspects three cognitive conspicuous areas, two of which are recognized as problem areas requiring further attention. (Fig. 3b) He then discovers a new problem area, which he controls during the 13th and 14th seconds. Next, two new problem areas receive attention and are solved after a short inspection (Fig. 3c and spike in Fig. 5). Then, verification begins. The dentist returns to the problem areas previously detected, inspects them again and compares the area with other areas on the X-ray. This verification process goes on until the 34th second. During the 35th and 36th seconds a discolouration indicating a visual conspicuous area is discovered (Fig. 3d).

The last 10 seconds are spent on checking the hypothesis. It is assumed that the last spike is an indication of the verbalisation of the diagnosis.

The student's eye movement pattern shows partitioning of the inspection process. As soon as a problem is presented, he tries to solve it.

The first part of the inspection process - taking about two seconds - yields three cognitive conspicuous areas. (Fig. 4a).

One problem is immediately solved as caries. During the next two seconds (Fig. 4b) the student inspects the second, followed by the third and a new area showing caries. The student continues inspecting the problem recognizing, in so doing, new cognitive conspicuous areas. Scanning and recognizing do not result in much mental load. From the 19th second until the end of the process the student proceeds with inspecting the cognitive conspicuous areas previously found.

One element is inspected carefully (Fig. 4e). The last spike (Fig. 5) is again assumed to mean verbalisation.

The first apparent difference to be noted is that the dentist first inspects the whole X-ray, and then tries to formulate solutions whereas the student tries to solve the problem immediately. The second difference concerns one particular visual conspicuous area, noticed by the dentist and causing a distraction. The student does not even notice this area, which suggests that his store of pathological patterns does not contain a comparable element. A third difference concerns the element which is inspected. The element inspected by the student shows no pathology, that inspected by the dentist shows a periapical lesion. It is remarkable that the dentist does not mention the pathology in his verbal report. The borders of the set of patterns being symptomatic of a pathology are too constrained and the dentist, being in doubt, does not mention the pathology.

A further difference concerns the caries areas. The student inspects these areas, the dentist does not. Both, however, mention these areas in their diagnoses.

Finally and somewhat remarkably, both the student and the dentist res-

trict their inspection to the left half of the X-ray. The right-half containing no evidence of pathology is not inspected!.

REFERENCES

- Adelson, B. Problem solving and the development of abstract categories in programming languages. Memory and Cognition, 9, 1981, 422-433.
- Elstein, A.S., Shulman, L.S. and Sprafka, S.A. (1978): Medical problem solving. Cambridge, MA. Harvard University Press.
- Engel, F.L. Visual conspicuity as an external determinant of eye movements and selective attention. Dissertation Eindhoven University of Technology, 1976.
- Groot, A.D. de. Thought and choice in chess. The Hague: Mouton. 1965.
- Johnson, P.E., Duran, A.S., Hassebrock, F., Moller, J., Prietula, M., Feltovich, P.J. & Swanson, D.B. Expertise and error in diagnostic reasoning. Cognitive Science, 6, 1982, 235-283.
- Johnson, P.E., Feltovich, P.J., Moller, J. & Swanson, D.B. Clinical expertise: Theory and data from diagnosis of congenital heartdisease. Paper presented at the AERA-congress, 1979.
- Kahneman, D. Attention and effort. Englewood Cliffs (N.J.), Prentice Hall, inc., 1973.
- Kreps, J., Kraft, R., Burris, R., Isch, R., Olson, F., Smith, S. & Karabinos, C. SQUIRE: Interactive computer-based excercises in diagnostic radiology. Paper presented at the AERA-congress, 1979.
- Kundel, H.L. & Lafollette, P.S. Visual search patterns and experience with radiological images. Radiology, 103, 1972, 523-528.
- Kundel, H.L. & Nodine, C.F. Studies of eye movements and visual search in radiology. In: J.W. Senders, D.F. Fischer and R.A. Monty (Eds.): Eye movements and the higher psychological functions. New York: Wiley, 1978.
- Kundel, H.L. & Wright, D.J. The influence of prior knowledge on visual search strategies during the viewing of chest radiographs. Radiology, 93, 1969, 315-320.

- Larkin, J.H., McDermott, J., Simon, D.P. & Simon, H.A. Models of competence in solving physics problems. Cognitive Science, 4, 1980, 317-348.
- Simon, D.P. & Simon, H.A. Individual differences in solving physics problems. In: R. Siegler (Ed.), Children's thinking what develops, LEA, New Jersey, 1978.
- Valk, J.P.J. de and Eijkman, E.G.J. An analysis of eye-fixations during the diagnostic interpretation of chest radiographs. Accepted for publication in: Medical and Biological Engineering and Computing (in press)

Table 1. Distribution of inspection points among conspicuous areas during the first second

	<u>Conspicuous areas</u>	
	visual	cognitive
students	25	97
dentists	12	115

Figure captions.

Figure 1. Average processing time as a function of problem type and level of expertise.

Figure 2. Average accuracy as a function of problem type and level of expertise.

Figure 3. Sections of the inspection process of a dentist.

Figure 4. Sections of the inspection process of a student.

Figure 5. Changes in pupil size during the inspection process of a dentist (dotted line) and of a student (solid line).

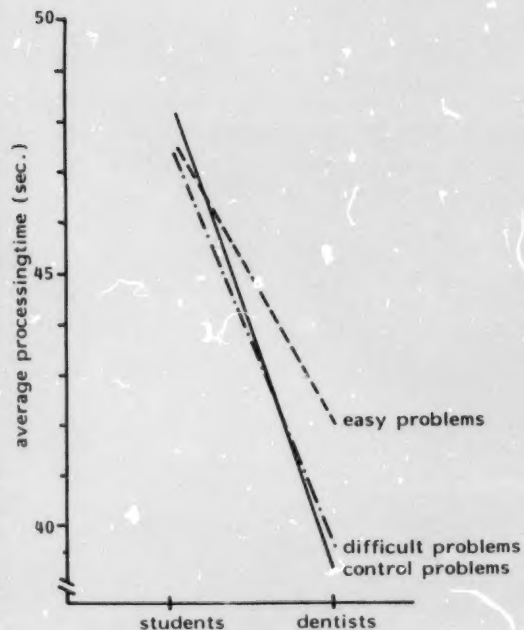


Figure 1:
Average processing time as a function
of problem type and level of expertise.

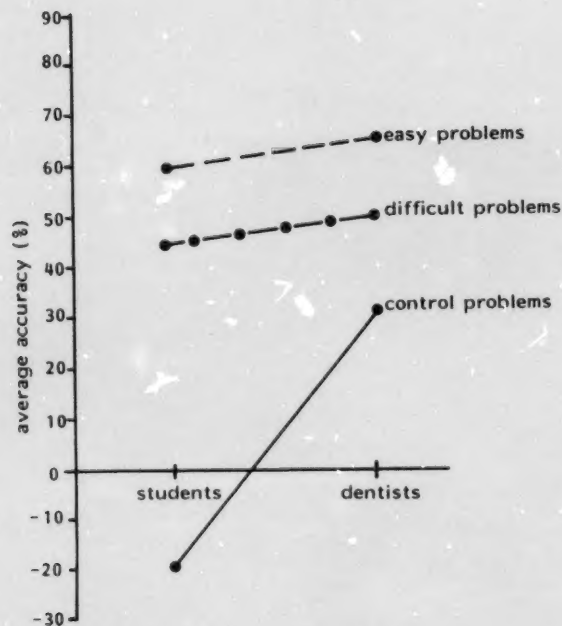


Figure 2:
Average accuracy as a function of
problem type and level of expertise.



3a: Seconds 1-2



3b: Seconds 7-8

Figure 3: Seconds of the inspection process of a dentist.

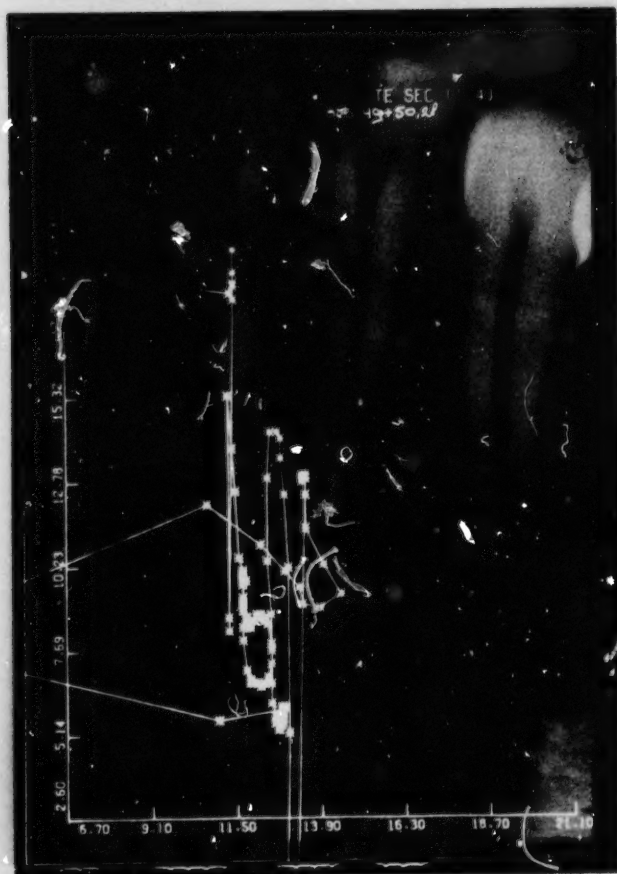


3c: Seconds 15-16



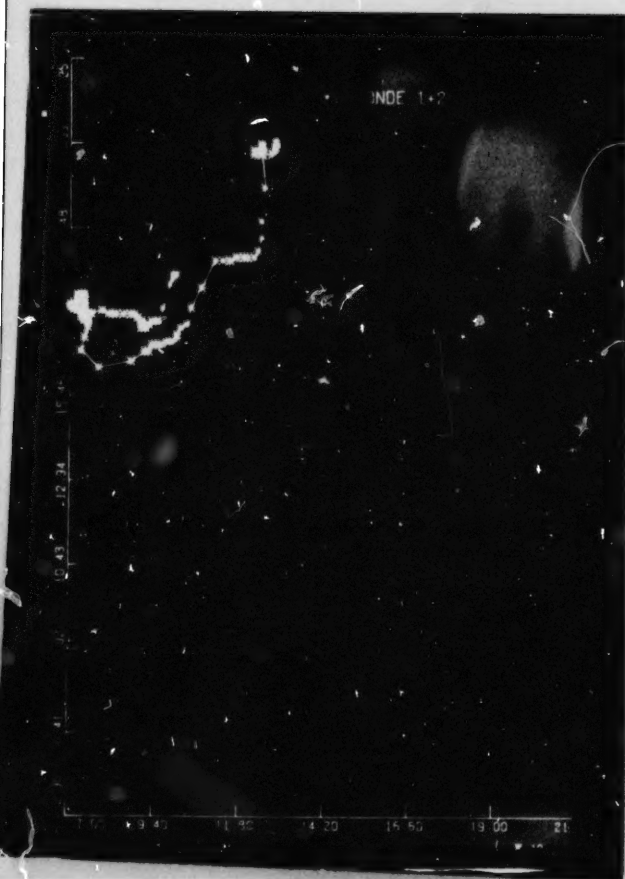
3d: Seconds 35-36

Figure 3: Sections of the inspection process of a dentist (continued).



3e: Last 2 seconds (49-50)

Figure 3: Sections of the inspection process of a dentist (continued).

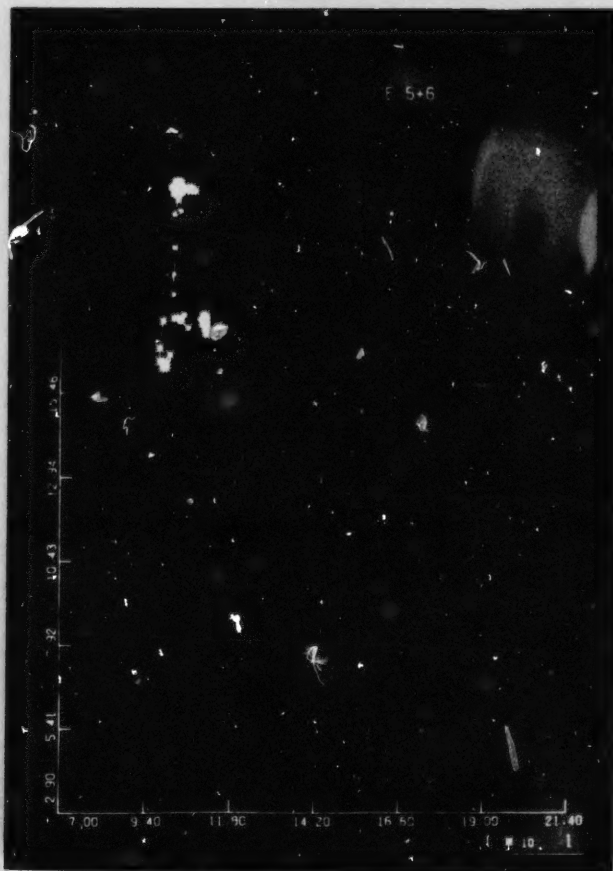


4a: Seconds 1-2



4b: Seconds 3-4

Figure 4: Sections of the inspection process of a student.



4c: Seconds 5-6



4d: Seconds 7-8

Figure 4: Sections of the inspection process of a student (continued).



4e: Last 2 seconds (27-28)

Figure 4: Sections of the inspection process of a student (continued).

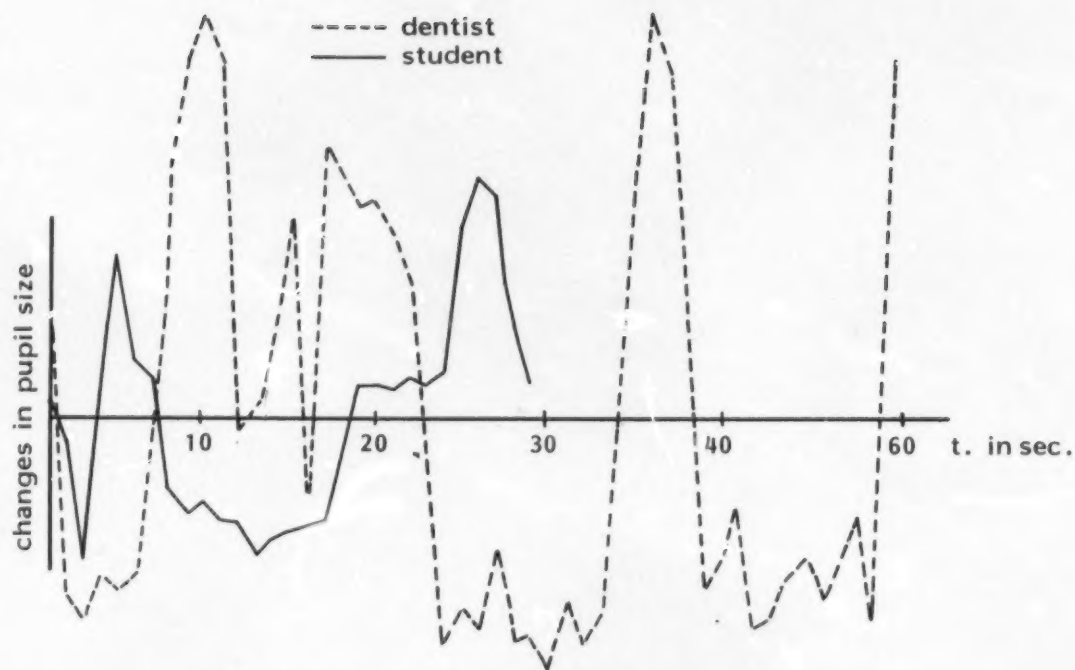


Figure 5:

Changes in pupil size during the inspection process of a dentist (dotted line) and of a student (solid line).